PROGRESS REPORT

BILLFISH RESEARCH SUPPORTED BY THE UNIVERSITY OF MIAMI, CENTER FOR SUSTAINABLE FISHERIES: 2001-2002

Carlos Rivero[1], Joseph Serafy[1], and Eric Prince[1]

Sustainable Fisheries Division Contribution SFD-02/03-181

The University of Miami's Center for Sustainable Fisheries (CSF) provided scientists at the Southeast Fisheries Science Center (SEFSC) with funds in the amount of $68,000 to pursue two main objectives. The first was to coordinate with CSF scientists by conducting Atlantic billfish movement and habitat utilization studies (as recommended by ICCAT Enhanced Research Program for Billfish) using pop-up satellite tags. The second objective was to improve access to, and analysis of, the various billfish tagging databases that have been maintained by the SEFSC's Migratory Fisheries Biology Branch for since 1978. The latter included providing geographical information system capability to databases that, until now, have been too archaic and unwieldy for rapid and advanced spatio-temporal analyses. Further details on the above follow.

1. POP-UP TAGGING STUDIES

Background

First implemented in 1987, the ICCAT Enhanced Research Program for Billfish (ERPB) is an ongoing international effort designed to develop the data necessary to manage and assess the status of Atlantic billfish stocks. Among the specific objectives of the program is to increase understanding of billfish movement and relationships between these fish and their pelagic habitat, particularly during critical life stages such as spawning. During 2002, our focus was on Atlantic blue marlin (*Makaira nigricans*), with field efforts based in the vicinity of Exuma Sound, Bahamas (Figure 1). This area has been confirmed to serve as both spawning and nursery habitat for this species. Our CSF-funded pop-up tag work builds on research conducted in 2000 and 2001, whereby very high concentrations of blue marlin larvae (both in and near Exuma Sound) were collected (highest catch rates ever reported; Serafy et al., in press). Given our larval age estimates, and assuming passive, surface transport, we determined that blue marlin spawning occurred in waters within or near the "triangle" of Rum Cay, San Salvador and Conception Islands. This prompted an effort to electronically tag adult blue marlin in waters within this "triangle" (as well as at locations further upstream) during June 2002 while also coordinating with collection efforts (spearheaded by CSF scientists) that targeted their potential larval progeny during July 2002.

---

1 NOAA Fisheries, Southeast Fisheries Science Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami, FL, 33149-1099, USA.

Results

Both the adult tagging and the larval research components were successful in 2002 – **a total of 25 adult blue marlin was tagged with pop-up satellite tags (40-day deployments) and, less than a month later, very high concentrations of larval blue marlin (108 individuals total) were collected in this area, for a third time in three years.** Figure 1 shows fish tagging and tag pop-up locations. We are currently in the process of analyzing adult movement and larval distribution data on blue marlin for publication in a peer-reviewed journal.

Our overall approach of sampling larvae for information on nursery habitat and electronic tagging of adults upstream for information on potential spawning habitat and behavior has provided valuable data. Research of this type serves as a "first-step" towards the ultimate protection of habitats that are essential for the Atlantic marlins, and possibly other highly-migratory, pelagic fishes, and critical in the effort rebuild their stocks. Furthermore, the larval sampling component of this study may also have a future role in the management of the Atlantic marlin stocks by providing data for an index of spawning stock biomass. In addition, electronic tagging data will have direct utility for estimating marlin bycatch mortality rates (past and future) in the commercial and recreational fisheries, and hence will be relevant as various measures are considered to reduce future marlin by-catches/discards. Moreover, electronic tagging of adults will also obtain data to define the vertical habitat of blue marlin, which is important to the stock assessment process. Documenting residence times for adult marlin on the spawning grounds is inherently valuable to the management process. Therefore, this study represents an important new line of investigation on these valuable, heavily exploited candidate species.

2. BILLFISH DATABASE DEVELOPMENT, VISUALIZATION AND ANALYSIS

Background

Advances in billfish biology and management require that appropriate data on both fish and fishery "movement" are obtained and analyzed. An understanding of the long-term (weeks to years), large-scale migrations of billfish populations is critical for defining, assessing, and ultimately managing their stocks. For example, prior to 1995, blue marlin were managed as western and eastern Atlantic stocks. However, largely because recent conventional and electronic tagging studies revealed trans-Atlantic and trans-Equatorial migrations (also corroborated by genetic studies of stock structure), blue and white marlin are now managed as a single Atlantic stock. Similarly, studies on short-term (days to weeks) post-release movement can be revealing of mortality rates associated with: (1) catch-and-release angling; and (2) the practice of discarding live, non-target fish that have been captured by commercial longline gear. Short-term archival and pop-up satellite tagging investigations, therefore, represent a direct and novel approach toward assessing specific fishery impacts.

The Migratory Fisheries Biology Branch has conducted several studies, and supports ongoing programs, that collect both long- and short-term spatially-explicit data on billfishes. Long-term data bases generated as part of the Cooperative Tagging Center (CTC) program span from 1954 to the present, and contain "at-sea" (conventional) tag and recapture locations for blue marlin, white marlin and sailfish. Although there have been several overviews of CTC data, comprehensive visualization and detailed spatial analyses on billfish have been limited.

Results

An initial assessment of the Cooperative Tagging Center (CTS) database revealed some significant limitations associated with the original design of the database. For example, the original design was based on managing and analyzing tag information. This "tag-centric" approach made it difficult to keep track of a specific animal since a given specimen could have multiple tags associated with it. This made reporting a complex process since each tag had to be traced back to the original record via queries involving multiple columns and rows (records). In addition, generating reports from this database required an intimate knowledge of the relationships between the records and their tag identifiers. In other words, the complexity of the system was not evident to the new users and, as such, increased the probability of producing inaccurate reports. Also, multiple records were kept to document a recapture and an immediate release. This artificially increased the number of records for a particular animal.

An alternative approach called for an "animal-centric" design where individual animals received unique identifiers and each interaction with the animal would receive the same identifier (Figure 2). In other words, the tags are used to identify an interaction with an animal, but not the animal itself. An interaction is defined by any human contact this animal may have had that resulted in the placing, identification, or recovery of a conventional, archival, or satellite tag. In essence, any unique interaction would have only one record in the database. This makes the reporting process less susceptible to logical errors since there is a one-to-one relationship between interactions and records. Furthermore, the history of an individual specimen can be traced by its identifier and not the tags that were placed on it.

Also, a web-based data entry and reporting system was developed to provide access to the CTS database (Figure 3). The original character-based data entry system developed for the CTS did not support the current needs of its users. The previous system required investigators, analysts, and data-entry personnel to have an in-depth knowledge of PL/SQL and UNIX system programming in order to manipulate records and generate reports. Although some reports and data entry procedures were developed by staff programmers, the accuracy of these reports could not be independently verified by the analyst. The new system provides users with record level access to the database via a graphical user interface. Users can search for individual anglers, animals, or interactions and can generate reports based on user-defined criteria. This open system makes it possible for users to verify the values contained within reports through queries.

The expected increase in deployment of pop-off archival tag (PAT) technology within our scientific research required the development of an automated approach to data acquisition, analysis, and reporting of PAT-generated data. The data collected and transmitted by the pop-off tags contain information on horizontal and vertical movements as well as temperature profiles for the deployment period. This data is transmitted by the tag to a Service Argos satellite and then distributed by the Automatic Distribution Service (ADS) via email. This distribution method limits the degree to which this process can be automated. Currently, investigators receive two emails from the ADS for each transmission collection period. The first email contains data describing the quality of the transmissions, the number of messages received, and two possible tag locations (in latitude/longitude format) during each satellite pass. The second email contains the histogram, location, and status data generated by the PAT. Wildlife Computers, Inc. has developed a proprietary application to process the email-distributed PAT data using macros contained within a Microsoft Excel workbook. Microsoft Excel is not a suitable platform for our application since multiple investigators and analysts are likely to need simultaneous access to the data. In addition, the Wildlife Computers application does not process the Argos transmission quality and location information. This made it necessary to develop additional algorithms to process, upload, and manage the Argos and PAT data within a multi-user database.

The redesign of the CTS database made it possible to incorporate the PAT data within the CTS since these tags were also surrogates for an interaction with an animal. The only difference between the PAT and conventional tags is that the pop-off tags have programming, deployment, and pop-off parameters that must be catalogued as well as the high-resolution data they transmit. This difference was addressed through the development of some additional tables within the CTS database. A PAT table was created to keep track of the programming parameters, deployment characteristics, and pop-off information associated with each tag. In other words, this table contained documentation unique to its respective tag. Several additional tables were developed to store post-transmission information such as time-at-depth, time-at-temperature, pat-depth-time, and Argos locations. A Java application was developed to process the Argos emails into a comma-delimited file. In addition, a Microsoft Excel macro was developed to process the proprietary worksheets into a format suitable for batch uploading.

An additional web-based analysis and reporting application was developed for the PAT data using the development methodology employed in the creation of the CTS application (Figure 4). Users have access to individual tag data including programming parameters, deployment and pop-off characteristics, time-at-depth, time-at-temperature, and geographic locations (Figure 5). Users can query the system for individual tags, copy the results from the web page, and paste into other software (e.g., Microsoft Excel, SAS, ArcView, etc.) for additional analyses. In addition, users can query the database from within such applications using the database driver provided with their system. In other words, this system provides multi-user access without imposing any additional platform or client-software limitations.

The new database has also been "spatially-enabled" to store, manage, and analyze the location information contained within the latitude and longitude fields of each record. An analysis of the spatial-reference potential for each table was conducted and the appropriate geometries were generated. For example, each interaction is best represented by point geometry while the animal's track is best represented by a multi-point line generated by its respective interactions. Geometry creation is an automated process that occurs each time a new spatial record is added to the system. This process allows investigators and analysts to conduct spatial queries and analyses without having to import the data into a mapping or GIS application. In addition, other geospatial datasets have been incorporated into the database like global bathymetry, country boundaries, habitat zones, sea surface temperature, and other types of base layers. In essence, the database has now become a geospatial information system (GIS).

We realize that the majority of the users that can benefit from access to geospatial data and associated functions do not need to acquire and learn how to use a GIS application. Although users can easily incorporate data from the system into their desktop applications, our goal is to provide sophisticated temporal and spatial analysis capabilities through a web-interface. To this end, we are currently working on developing visualization and analysis functionality similar to that available through ArcGIS. Although there are limitations to this system, it is important to note that it can be modified and expanded to accommodate additional data, analyses, and reports due to its open design and continued development. In the future, prototype analysis methodologies can be developed and tested in other applications like Microsoft Excel, SPSS, SAS, and ArcGIS then incorporated into the system by replicating the application logic in Java (Figure 6).

REFERENCES

Serafy, J.E., R.K. Cowen, C.B. Paris, T.R. Capo & S.A. Luthy (*in press*) Evidence of blue marlin, *Makaira nigricans*, spawning in the vicinity of Exuma Sound, Bahamas. *Marine and Freshwater Research*.

FIGURE LEGEND

Figure 1. Map indicating tag deployment and pop-up locations associated with of CSF-funded billfish research.

Figure 2. Data model for CTS database with PAT data tables.

Figure 3. CTS web-based data entry and reporting system.

Figure 4. Web-based data entry and reporting system displaying registered Pop-off Archival Tags.

Figure 5. Web-based data entry and reporting system showing Time at Depth data for Pop-off Archival Tag 22872.

Figure 6. CTS computer infrastructure.

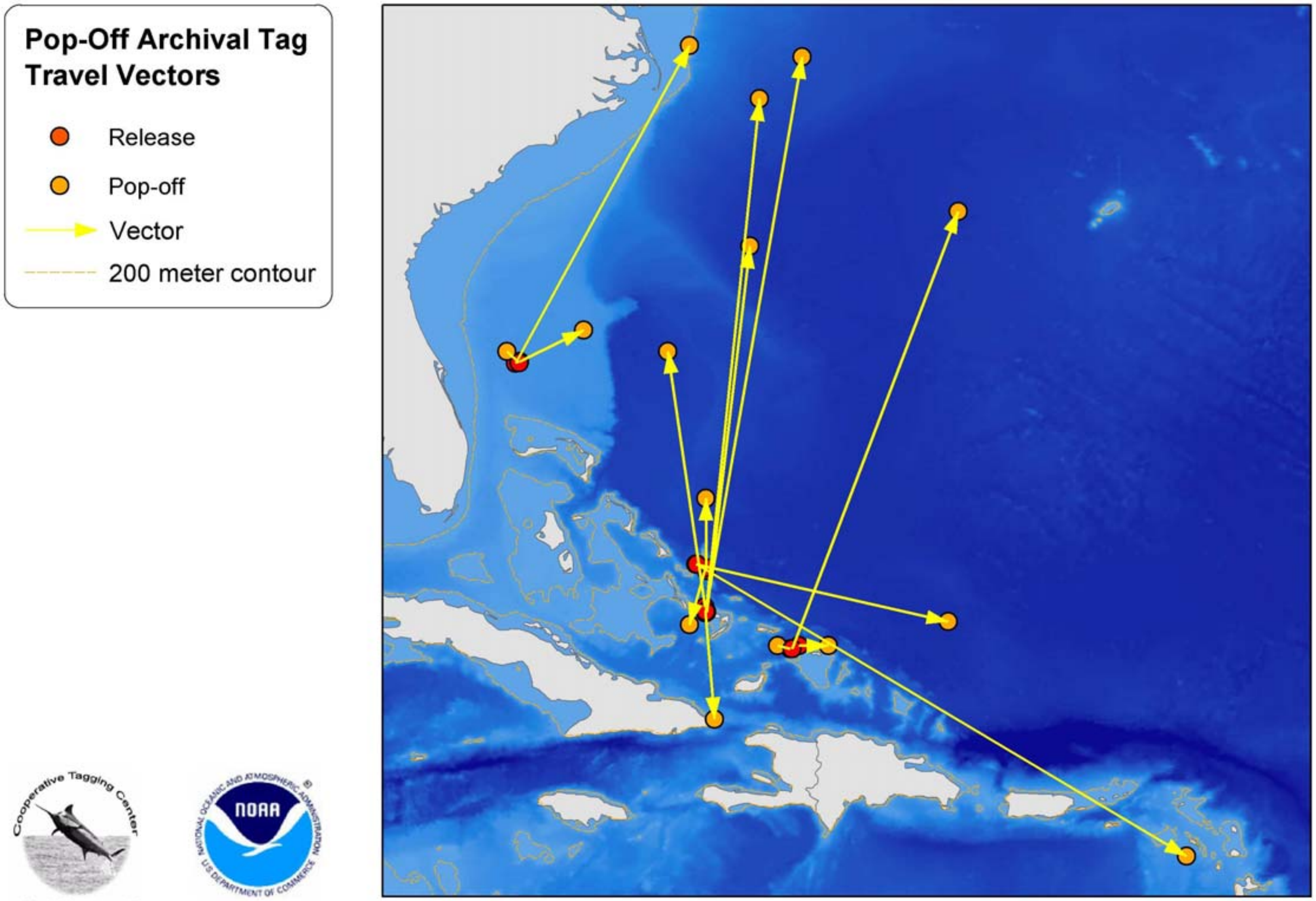

Photo Courtesy of
Guy Harvey

Figure 1. Map indicating tag deployment and pop-off locations associated with CSF-funded billfish research.

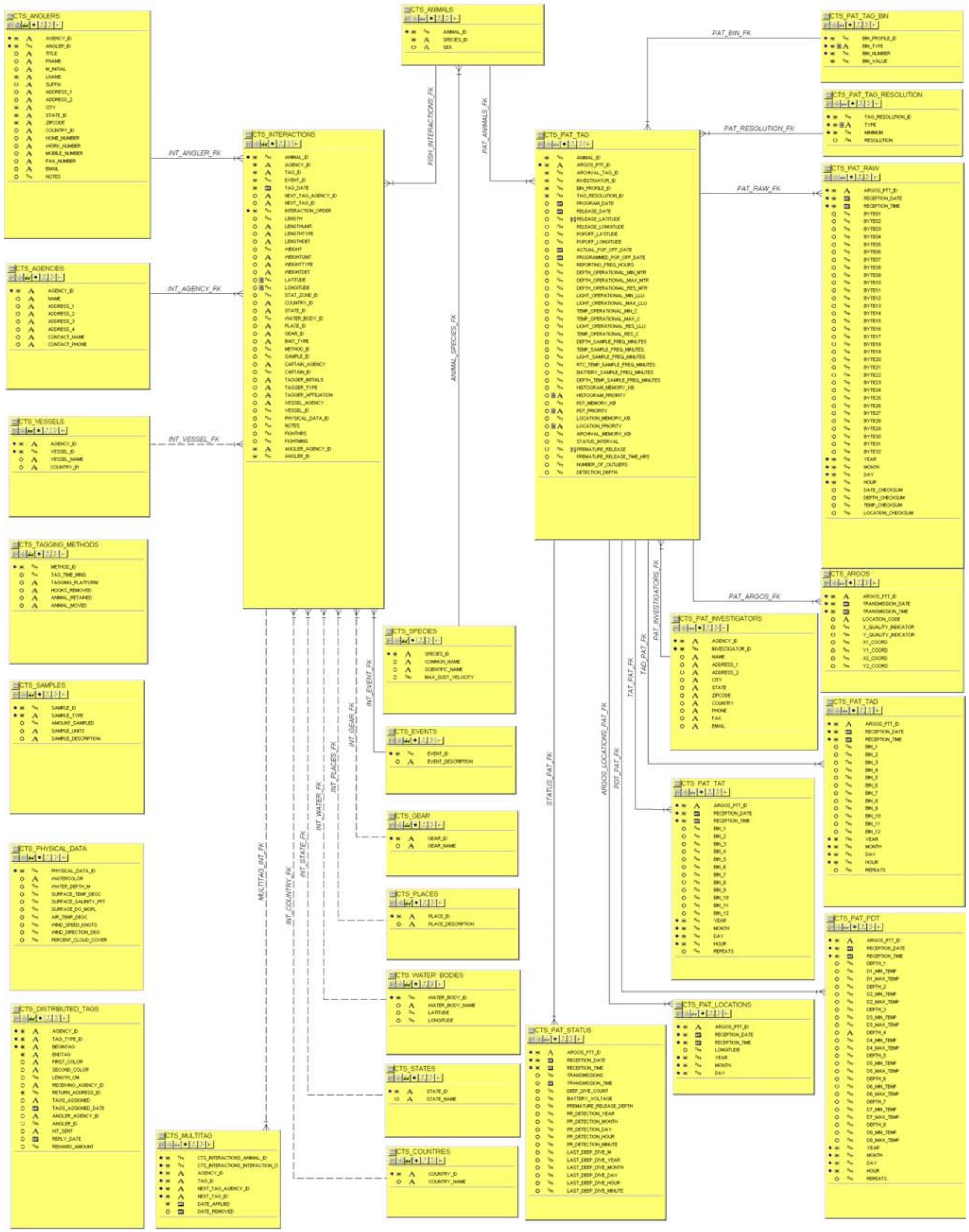

Figure 2. Data model for CTS database with PAT data tables.

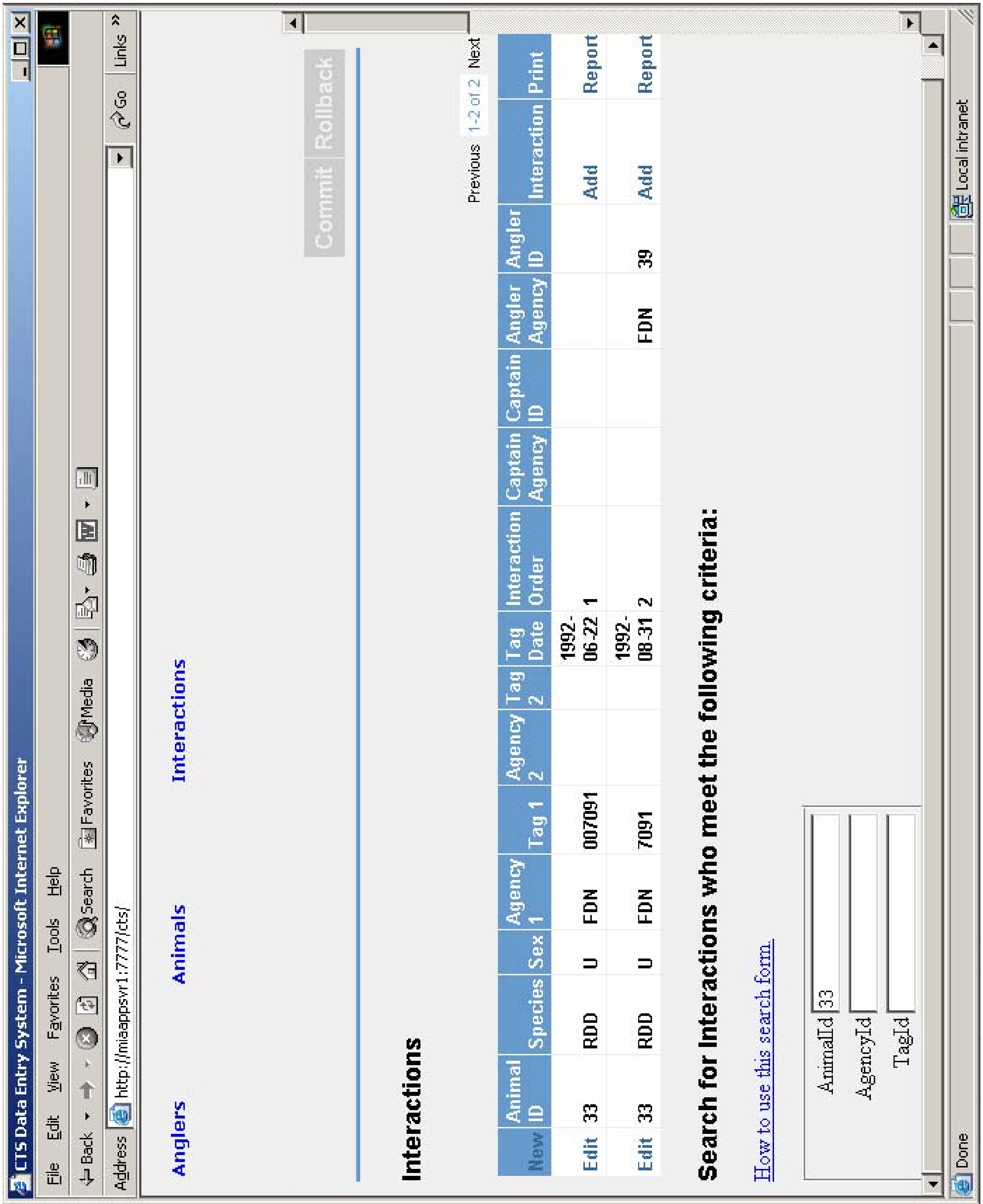

Figure 3. CTS web-based data entry and reporting system.

Figure 4. Web-based data entry and reporting system displaying registered Pop-off Archival Tags.

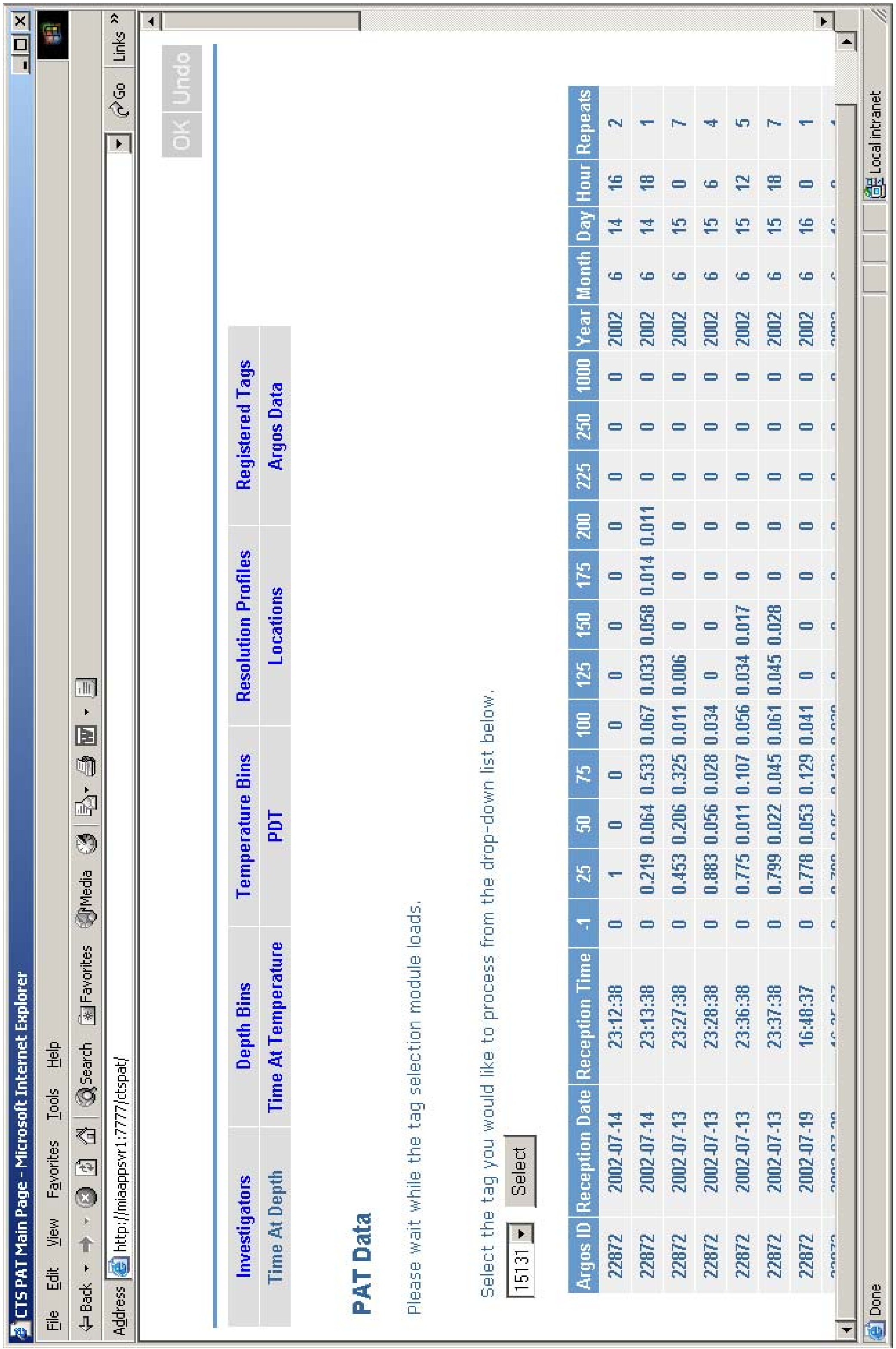

Figure 5. Web-based data entry and reporting system showing Time at Depth data for Pop-off Archival Tag 22872

.

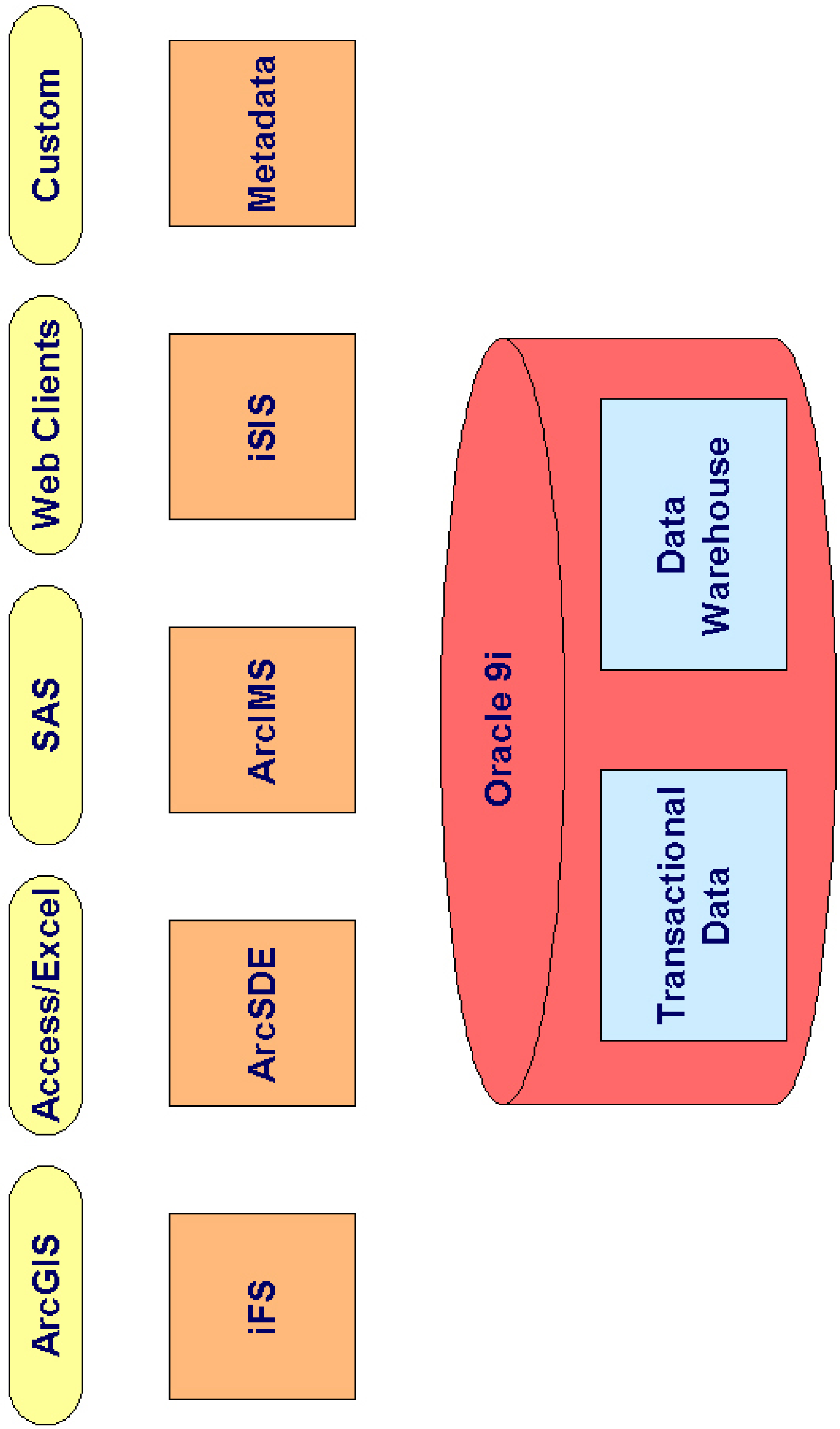

Figure 6. CTS computer infrastructure.